

## A Quick Guide to AASHTO LRFD at Caltrans, With reference to present LFD Methods

| Concept  | <i>AASHTO LRFD Bridge Design Specifications w/Caltrans Amendments</i>  | <i>Caltrans Bridge Design Specifications, based on AASHTO Standard Specs</i>   |
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| GENERAL  |  |  |
| Scope  | Structural and Geotechnical  | Structural   |
| Notation <ul style="list-style-type: none"> <li>Stress</li> <li><math>\phi</math></li> </ul>                                 | <ul style="list-style-type: none"> <li><math>f</math> (Note: This change eliminates confusion with <math>\sigma</math>=standard deviation as used in the calibration.)</li> <li>“resistance factor”</li> </ul>   | <ul style="list-style-type: none"> <li><math>\sigma</math></li> <li>“strength reduction factor”</li> </ul>   |
| Primary Design Method  | LRFD—Eqn. 1.3.2.1<br>$\phi R_n \leq \sum \eta_i \gamma_i Q_i$<br>Note: $\eta_i=1.0$ at Caltrans  | LFD—Eqn. 3-10<br>( $Group N$ ) = $\gamma[\sum \beta_i Q_i]$  |
| Safety (LL’s)  | Calibrated to $P_f = 1 : 4200$   | Experience-based   |
| Scour Considerations <ul style="list-style-type: none"> <li>Footing locations</li> <li>Stability</li> <li>Seismic</li> </ul> | <ul style="list-style-type: none"> <li>Top-of-pile cap above degradation+contraction. Bottom-of-pile-cap above degradation + contraction + local pier scour, unless piles are designed for bending (2.6.4.4.2).</li> <li>Factored live loads with 50% channel degradation</li> <li>Seismic loads with degradation effects, only</li> </ul> | <ul style="list-style-type: none"> <li>“Footings on piles may be located above the lowest anticipated scour level provided the piles are designed for this condition.” (4.4.2.2)</li> <li>Not specified</li> <li>Varies</li> </ul> |
| Slab thickness, min.   | Table 2.5.2.6.3-1 Additional cover of 0.5 in. required when grinding is anticipated.   | Table 8.9.2  |
| Seismic  | CA <i>Seismic Design Criteria</i> superceeds <i>AASHTO LRFD</i> provisions   | CA <i>Seismic Design Criteria</i> superceeds <i>AASHTO Std Specs</i> , CA <i>BDS</i> provisions  |
| Temporary structures   | <ul style="list-style-type: none"> <li>“temporary” defined as 5 years (3.10.10)</li> <li>MTD 15-14 applies to both LFD and LRFD</li> </ul>   | Not addressed  |
| LOADS  |  |  |

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| Vehicular LL   | HL93 (3.6.1.2): HS20 truck or tandem, AND HS20 lane load   | HS20 truck, alternate military vehicle, or HS20 lane load   |
| Short, heavy LL  | "Design Tandem"--Two 25 <sup>k</sup> axles, 4' c-c (3.6.1.2.3)   | "Alternate Military Load"--Two 24 <sup>k</sup> axles, 4' c-c (3.7.4)  |
| Vehicular Live Loads, -M and reactions   | <ul style="list-style-type: none"> <li>90%*[Two trucks, 50 ft min. between axles+lane load]</li> <li>100%[Two tandems, 50 ft. between ft., rear axles]</li> </ul>  | HS20 lane loading with shear, moment riders (3.7.6)   |
| Braking; longitudinal forces   | 3.6.4 25% of truck or tandem; 5% of truck or tandem + lane   | 3.9.1 5% of HS 20 truck   |
| Permit Design Live Loads   | P15 longdeck (3.6.1.7)   | P5, P7, P11, P13 (Figure 3.7.7B)  |
| Column collision   | 400 <sup>k</sup> (3.6.5.2)   | Not addressed   |
| Surcharge <ul style="list-style-type: none"> <li>abutments</li> <li>retaining walls</li> </ul>   | 3.11.6.4 (due to LL only; separate load for earth) <ul style="list-style-type: none"> <li>2 to 4 ft depending on ht, may be reduced with slab</li> <li>2 to 5 ft depending on ht, 2 ft if traffic is <math>\geq</math> 1ft away</li> </ul>   | 3.20.3 <ul style="list-style-type: none"> <li>2 ft, if traffic is within one-half the wall ht away</li> <li>2 ft, if traffic is within one-half the wall ht away</li> </ul>   |
| Temperature <ul style="list-style-type: none"> <li>Longitudinal</li> <li>Vertical</li> </ul>   | 3.12 <ul style="list-style-type: none"> <li>TU—Procedure A w/2 air ranges; Procedure B w/maps and movement eq.</li> <li>TG—FYI; not in CTBridge</li> </ul>   | 3.16 <ul style="list-style-type: none"> <li>3 air ranges, concrete and steel</li> <li>not addressed</li> </ul>  |
| Load Factors <ul style="list-style-type: none"> <li>Dead load</li> <li>Wearing surface, utilities</li> <li>Dynamic Load Allowance (Impact)</li> <li>Multiple Presence</li> </ul> | Table 3.4.1-1 <ul style="list-style-type: none"> <li>Maximum and minimum <math>\gamma</math>'s provided in Table 3.4.1-2</li> <li>Less predictable than deck, girders; higher load factor</li> <li>IM=33% (Table 3.6.2.1-1)<br/>Note: 75% at joints; 15% for fatigue</li> <li>Included in load distribution tables; 1.2 for 1 lane, 1.0 for 2 lanes, 0.85 for 3 lanes, 0.65 for 4 lanes</li> </ul> | Table 3.22.1A <ul style="list-style-type: none"> <li>Footnote to Table 3.22.1A regarding <math>\beta = 0.75</math></li> <li>Same load factor as deck, girders</li> <li>3.8.2 <math>I=50/(L+125)</math></li> <li>100% for 2 lanes; 90% for 3 lanes; 75% for <math>\geq</math> 4 lanes</li> </ul> |
| Load Combinations <ul style="list-style-type: none"> <li>Service loads</li> <li>Overloads</li> <li>Widely-spaced</li> <li>Subst. Design</li> <li>Wind</li> </ul>                 | Table 3.4.1-1 <ul style="list-style-type: none"> <li>Strength I</li> <li>Strength II (2 lanes)</li> <li>Strength II (refined anal.)</li> <li>Strength II-sub</li> <li>Strength III</li> </ul>  | Table 3.22.1A <ul style="list-style-type: none"> <li>Group IH</li> <li>Group IPC</li> <li>Group IPW, Group IP3D</li> <li>Group IPW</li> <li>Group II</li> </ul>   |

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| <ul style="list-style-type: none"> <li>• DL only</li> <li>• Wind+LL</li> <li>• Earthquake</li> <li>• Prestressing</li> <li>• Fatigue</li> </ul>                    | <ul style="list-style-type: none"> <li>• Strength IV (long-span br.)</li> <li>• Strength V</li> <li>• Extreme Event I</li> <li>• Service I, III</li> <li>• Fatigue I, II-III (coming)</li> </ul>  | <ul style="list-style-type: none"> <li>• (not addressed)</li> <li>• Group III</li> <li>• Group VII</li> <li>• Group I, Table 3.22.1B</li> <li>• (not addressed in Chpt. 3)</li> </ul>   |
| ANALYSIS   | Note: axles not contributing to extreme force effect are neglected (3.6.1.3.1)  |   |
| LL Distribution for <ul style="list-style-type: none"> <li>• beam-slab bridges</li> <li>• concrete box girders</li> <li>• decks</li> <li>• slab bridges</li> </ul> | <ul style="list-style-type: none"> <li>• Expressions in 4.6.2.2.____-____ Moment, interior girder, 2b-1 Moment, exterior girder, 2d-1 Shear, interior girder, 3a-1 Shear, exterior girder, 3b-1</li> <li>• Whole-width design—take interior girder factors, above, and multiply by number of girders. Range of applicability expanded per study by UCD.</li> <li>• Strength method with equivalent strip widths, Table 4.6.2.1.3-1. HL93 design moments in A4-1.</li> <li>• For one design lane loaded, Eq. 4.6.2.3-1<br/> <math display="block">E = 10.0 + 5.0\sqrt{L_1 W_1}</math> </li> <li>• For two design lanes loaded, Eq. 4.6.3.2-2<br/> <math display="block">E = 84.0 + 1.44\sqrt{L_1 W_1} \leq \frac{12.0W}{N_L}</math> </li> <li>• <math>L_1</math>=span length &lt; 60 ft<br/> <math>W_1</math>&lt;30 ft (1 lane);60 ft (2+lane)</li> <li>• Edge bm dgn—1 lane of wheels (4.6.2.1.4b)</li> </ul> | <ul style="list-style-type: none"> <li>• “s-over” per Table 3.23.1, unlimited range of applicability</li> <li>• “overall width÷7” per Table 3.23.1; unlimited range of applicability</li> <li>• Working Stress (3.24.3.1);<br/> <math>M=P^*(S+2)/32</math> ft-k/ft</li> <li>• Distribution width, <math>E</math>, for one lane of traffic is <math>(4+0.06S)&lt;7</math>ft, for truck loads; and <math>2E</math> for lane loads (reinforcement parallel to traffic). 3.24.3.2</li> <li>• Not designed for, but 2 #10's T &amp; B (BDA)</li> </ul> |
| Skew—LL's  | BDA p5-32 or shell-model  | BDA p5-32   |
| Braced, unbraced frames; effective length factors  | 4.6.2.5 CA amendments, AASHTO '06 Interims  | Not addressed   |
| CONCRETE   |   |   |
| Methodology  | Unified Concrete Design   | RC and PS separate  |
| Units, Terminology   | <ul style="list-style-type: none"> <li>• <math>f'_c</math> (KSI)</li> <li>• compression member</li> </ul>   | <ul style="list-style-type: none"> <li>• <math>f'_c</math> (PSI)</li> <li>• column</li> </ul>   |

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|   | <ul style="list-style-type: none"> <li>flexural member</li> </ul>   | <ul style="list-style-type: none"> <li>beam</li> </ul>  |
| Lightweight concrete  | '05 Interims for shear, flexure based on recent research  | Recent research NOT incorporated  |
| Service load combo's for allowable $f$ check  | Service I—compression<br>Service III--tension<br>Table 3.4.1-1, AASHTO LRFD   | SLD Group I on Table 3.22.1B of BDS April '00   |
| Allowable Stresses <ul style="list-style-type: none"> <li>Concrete</li> </ul>   | Before losses <ul style="list-style-type: none"> <li>Compression (5.9.4.1.1): <math>f_{ci}=0.60f_{ci}</math></li> <li>Tension (Table 5.9.4.1.2-1): <math>0.0948\sqrt{f'_{ci}} &lt; 0.200</math> ksi w/o bonded reinforcement; <math>0.24\sqrt{f'_{ci}}</math> w/ bonded reinforcement</li> </ul> After losses, compression (Table 5.9.4.2.1-1): <ul style="list-style-type: none"> <li>DL+PS, only: <math>0.45f'_c</math></li> <li>DL+PS+LL: <math>0.60f'_c</math></li> <li><math>0.5(DL+PS)+LL</math>: <math>0.40f'_c</math></li> </ul> After losses, tension (Table 5.9.4.2.2-1): <ul style="list-style-type: none"> <li>Bonded tendons: <math>0.190\sqrt{f'_c}</math></li> <li>Unbonded tendons: not used at Caltrans</li> </ul> | Before losses (9.15.2.1) <ul style="list-style-type: none"> <li>Compression, post-tensioned: <math>f_{ci}=0.55f_{ci}</math></li> <li>Compression, pre-tensioned: <math>f_{ci}=0.60f_{ci}</math></li> <li>Tension: 200 psi or <math>3\sqrt{f'_{ci}}</math> psi w/o bonded reinforcement; <math>7.5\sqrt{f'_{ci}}</math> w/bonded reinforcement</li> </ul> After losses (9.15.2.2), compression: <ul style="list-style-type: none"> <li><math>0.40f'_c</math></li> </ul> After losses (9.15.2.2), tension: <ul style="list-style-type: none"> <li><math>6\sqrt{f'_c}</math> psi</li> <li>Env. Area III, <math>3\sqrt{f'_c}</math> psi</li> <li>DL, only: 0</li> </ul> |
| <ul style="list-style-type: none"> <li>Stressing Steel</li> </ul>   | At transfer (Table 5.9.3-1) <ul style="list-style-type: none"> <li>Post-tensioned: <math>0.75f_{pu}</math></li> <li>Pre-tensioned: <math>0.75f_{pu}</math></li> </ul> In service (Table 5.9.3-1) <ul style="list-style-type: none"> <li><math>0.80*0.90f'_s</math></li> <li>Low-relaxation strand: <math>0.80*0.85f'_s</math></li> </ul>  | At transfer (9.15.1) <ul style="list-style-type: none"> <li>Post-tensioned: <math>0.70f'_s</math></li> <li>Pre-tensioned: <math>0.70f'_s</math></li> <li>Pre-tensioned, low-relaxation strand: <math>0.75f'_s</math></li> </ul> In service (9.15.1) <ul style="list-style-type: none"> <li><math>0.80*0.90f'_s</math></li> <li>Low-relaxation strand: <math>0.80*0.85f'_s</math></li> </ul>   |
| Losses (post-tensioning) <ul style="list-style-type: none"> <li>Anchor Set</li> <li>Friction</li> <li>Elastic Shortening</li> <li>Long-term losses (low lax)</li> </ul> | (5.9.5) <ul style="list-style-type: none"> <li>0.375 in.</li> <li><math>K=0.0002</math>; <math>\mu=</math> (varies)</li> <li><math>ES=[(N-1)/2N]*f_{cgp}E_p/E_{ci}</math></li> <li>25 ksi (CA amended per UCSD, 5.9.5.3)</li> </ul>   | (9.16.2.2) <ul style="list-style-type: none"> <li>0.375 in.</li> <li><math>K=0</math>; <math>\mu=0.2</math></li> <li>Included with estimated long-term losses</li> <li>20,000 psi</li> </ul>  |

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| <p>Losses (pre-tensioning)</p> <ul style="list-style-type: none"> <li>Elastic Shortening</li> <li>Long-term losses (low lax)</li> <li>Total losses</li> </ul>  | <ul style="list-style-type: none"> <li><math>ES = f_{cgp} E_p / E_{ci}</math></li> <li>Shrinkage = <math>12(1.7 - 0.01H)(5/(1 + f_{ci}))</math><br/>Creep = <math>10(f_{pi} A_{ps} / A_g)(1.7 - 0.01H)(5/(1 + f_{ci}))</math><br/>Relaxation = 2.5 ksi<br/>(Totalled in Eq. 5.9.5.3-1)</li> <li>ES + long-term losses</li> </ul>   | <p>(9.16.2.2)</p> <ul style="list-style-type: none"> <li>Included with estimated long-term losses</li> <li>22,000 psi</li> <li>35,000 psi</li> </ul>   |
| <p>Flexural Design (concrete)</p> <ul style="list-style-type: none"> <li>capacity—rectangular section</li> <li>capacity—flanged section</li> <li>maximum reinforcement</li> <li>minimum reinforcement</li> </ul> | <p>(Unified Concrete Theory) 5.7.3.2</p> $M_n = A_{ps} f_{ps} (d_p - \frac{a}{2}) + A_s f_y (d_s - \frac{a}{2})$ $M_n = A_{ps} f_{ps} (d_p - \frac{a}{2}) + A_s f_y (d_s - \frac{a}{2}) + 0.85 f'_c (b - b_w) h_f (\frac{a}{2} - \frac{h_f}{2})$ <p>5.7.2.1; 5.7.3.3.1<br/>Conventional RC<br/>Limit strain to 0.004</p> <p>Prestressed—use appropriate overstrength (resistance) factor, instead (CA '05 amendment, '06 AASHTO Interim)*</p> $\phi M_n \geq \min(1.2 M_{cr}, 1.33 M_u)$ | <p>Conventional RC</p> $M_n = [A_s f_y (d - \frac{a}{2})] \quad (8-16)$ <p>Prestressed Concrete (9-13)</p> $M_n = A_{s}^* f_{su}^* d (1 - 0.6 \frac{\rho^* f_{su}^*}{f'_c})$ <p>Conventional RC (8-19)</p> $M_n = (A_s - A_{sf}) f_y (d - \frac{a}{2}) + A_{sf} f_y (d - 0.5 h_f)$ <p>Prestressed Concrete (9-14)</p> $M_n = A_{sr} f_{su}^* d (1 - 0.6 \frac{A_{sr} f_{su}^*}{b' d f'_c}) + 0.85 f'_c (b - b') t (d - 0.5 t)$ <p>Conventional RC</p> $\rho_{max} \leq 0.75 \rho_{bal} \quad (8.16.3.1.1)$ <p>Prestressed Concrete (9.18.1)</p> $\rho^* \frac{f_{su}^*}{f'_c} \leq 0.30 \quad (9-20)$ $\frac{A_{sr} f_{su}^*}{b' d f'_c} \leq 0.30 \quad (9-21)$ <p>Conventional RC (?)<br/>Prestressed Concrete</p> $\phi M_n \geq 1.2 M_{cr} \quad (9.18.2.1)$ |
| $\phi_b$ (strength)  | *PC varies from 0.85 in  |  |

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|   | compression-controlled to 1.0 in tension-controlled regions; CIP PS—0.85 to 0.95; RC—0.85 to 0.90  | $\phi=0.90$ (except Group VII)  |
| Crack control   | $s \leq \frac{700\gamma_e}{\beta_s f_s} - 2d_c; \text{ decks } \gamma_e=0.75$ $\beta_s = 1 + \frac{d_c}{0.7(h-d_c)} \quad (5.7.3.4-1)$   | $f_s = \frac{z}{(d_c a)^{\frac{1}{3}}} \leq 0.6f_y \quad (8-61)$  |
| Bar cut-offs for positive or negative moment reinforcing  | <p>Based on flexural and shear resistance (horizontal component of inclined compression diagonals) needed at section, plus <math>l_d</math> requirements 5.8.3.5-1</p> $T = \frac{M_u}{d_v \phi} + 0.5 \frac{N_u}{\phi} + \left( \frac{V_u}{\phi} - 0.5V_s - V_p \right) \cot \theta$  | $l_d \leq \frac{M}{V} + l_a$  |
| <p>Shear (concrete)</p> <ul style="list-style-type: none"> <li>Resistance (typical flexural members)</li> </ul> | <p>“Sectional Method”- <math>V_c</math> now depends on applied strain, <math>\epsilon</math>. Total is lesser of (5.8.3.3):</p> $V_n = V_c + V_s + V_p$ $V_n = 0.25f'_c b_v d_v + V_p$ <p>for which</p> $V_c = 0.316\beta \sqrt{f'_c} b_v d_v$ $V_s = \frac{A_v f_y d_v (\cot \theta + \cot \alpha) \sin \alpha}{s}$ <p>Obtain <math>\theta</math> and <math>\beta</math> by calculating strain (<math>\epsilon</math>) and reading off Fig. 5.8.3.4.2-1. One iteration required. Alternatively, use</p> $\beta = \frac{4.8}{1+1500\epsilon_x}; \quad \theta = 29 + 7000\epsilon_x$ <p>(5.8.3.4.3)</p> | <p><math>V_c</math> based on flexural cracking + empirical safe margin</p> <p>Convention RC</p> $V_n = V_c + V_s \text{ where}$ $V_c = 2\sqrt{f'_c} b_w d$ $V_s = \frac{A_v f_y d}{s}$ <p>Prestressed Concrete</p> $V_n = V_c + V_s \text{ where}$ $V_s = \frac{A_v f_{sy} d}{s}, \text{ and}$ <p><math>V_c</math> is the lesser of <math>V_{ci}</math> and <math>V_{cw}</math></p> $V_{ci} = 0.6\sqrt{f'_c} b' d + V_d + \frac{V_i M_{cri}}{M_{max}}$ $V_{cw} = (3.5\sqrt{f'_c} + 0.3f_{pc}) b' d + V_p$ |
| <ul style="list-style-type: none"> <li>Short, deep members</li> </ul>   | <p>Use Strut-and-Tie</p> <ul style="list-style-type: none"> <li>Distance from point of zero-shear to face of support is <math>&gt; 2d</math></li> <li>Plane sections don't remain plane i.e. abrupt change in cross-section i.e.</li> <li>Load causing more than <math>\frac{1}{2}</math> of the shear at a support is</li> </ul>  | <p>(same as above)</p>  |

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| <ul style="list-style-type: none"> <li>• <math>\phi_v</math></li> </ul>   | <p>closer than 2d from the face of support</p> <ul style="list-style-type: none"> <li>• 0.90</li> </ul>  | <ul style="list-style-type: none"> <li>• 0.85</li> </ul>  |
| Torsion   | Addressed  | Not addressed   |
| Tendon debonding  | Addressed (5.11.4.3)   | Not addressed   |
| <p>Fatigue resistance</p> <ul style="list-style-type: none"> <li>• reinforcing bars</li> <li>• prestressing tendons</li> </ul>  | <ul style="list-style-type: none"> <li>• Check not required for deck slabs in multi-girder applications. Required only if compressive stress is less than twice the tensile live load stress from fatigue load combination.</li> </ul> <p>5.5.3.2 Reinforcing bars:</p> $f_r = 21 - 0.33f_{\min} + 8\left(\frac{r}{h}\right) \text{ ksi}$ <ul style="list-style-type: none"> <li>• 18.0 ksi for radii of curvature &gt; 30ft; 10.0 ksi for radii of curvature ≤ 12.0 ksi.</li> </ul> | $f_r = 21 - 0.33f_{\min} + 8\left(\frac{r}{h}\right) \text{ ksi}$ <ul style="list-style-type: none"> <li>• not addressed</li> </ul>   |
| Column $\phi$   | Varies; terminology changed to “compression-controlled”  | $\phi = 0.75$ with spirals<br>$\phi = 1.00$ for seismic   |
| Compression   | <p>5.7.4.4--<math>P_{n(\max)}</math> same as LFD</p> <p>5.7.4.5—biaxial same as LFD</p>  | <p>8.16.4.2--<math>P_{n(\max)}</math></p> <p>8.16.4.3—biaxial</p>   |
| Shear transfer (shear friction)   | <p>5.8.4</p> $V_n = cA_{cv} + \mu[A_{vf}f_y + P_c]$ <p>not to exceed:</p> $V_n \leq 0.2f'_cA_{cv} \text{ or } V_n \leq 0.8A_{cv}$  | <p>8.16.6.4.4</p> $V_n = A_{vf}f_y\mu$ <p>not to exceed:</p> $V_n \leq 0.2f'_cA_{cv} \text{ or } V_n \leq 0.8A_{cv}$  |
| Pierwalls (reinforcing reqm.)   | <p>5.10.11.4.2</p> $\rho_v, \rho_h > 0.0025$ ; 18-in. max c-c  | <p>MTD 6-5 <math>\rho_h &gt; 0.0025</math>; 12-in. c-c horz., 6-in. max c-c vert.</p>   |
| <p>Inverted-T Bent Cap</p> <ul style="list-style-type: none"> <li>• effective ledge width, shear</li> <li>• effective width, punching shear</li> <li>• effective ledge width, flexure</li> <li>• inclined stirrups</li> <li>• primary reinforcement</li> <li>• secondary tension reinforcement</li> </ul> | <p>5.13.2.5</p> <ul style="list-style-type: none"> <li>• Pad width + 4*<math>a_v</math> (<math>a_v</math> is distance to shear reinf.)</li> <li>• Pad width + 2*effective depth</li> <li>• Pad width + 5*<math>a_f</math> (<math>a_f</math> is distance to flexure reinf.)</li> <li>• Use regular shear equations; angle = <math>\alpha</math></li> <li>• <math>A_s \geq \frac{2A_{vf}}{3} + A_n; A_f + A_n</math></li> <li>• <math>A_h \geq 0.5(A_s - A_n)</math></li> </ul>        | <ul style="list-style-type: none"> <li>• Pad width + effective depth(?)</li> <li>• Pad width + effective depth</li> <li>• Pad width + effective depth</li> <li>• <math>V_n = A_{vf}f_y(\mu \sin \alpha_f + \cos \alpha_f)</math></li> <li>• <math>A_s \geq \frac{2A_{vf}}{3} + A_n; A_f + A_n</math></li> <li>• <math>A_h \geq 0.5(A_s - A_n)</math></li> </ul> |
| Footing Shear   | 5.13.3.6   | 8.16.6.2.1  |

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| <ul style="list-style-type: none"> <li>One-way Action</li> <li>Two-way Action</li> </ul>  | <p>Sectional method--see shear design, above, and 5.8.3.4.1.</p> $V_n = V_c + V_s \leq 0.192\sqrt{f'_c}b_o d$ $V_c = 0.0632\sqrt{f'_c}b_o d_v \text{ ksi}$ $V_s = \frac{A_v f_y d_v}{s} \text{ ksi}$   | $V_n = V_c + V_s; V_s = \frac{A_v f_y d_v}{s}$ $V_c = (1.9\sqrt{f'_c} + 2,500\rho_w \frac{V_u d}{M_u})b_w d$ <p>or <math>V_c = 2\sqrt{f'_c}b_w d</math></p> $V_c = (2 + \frac{4}{\beta_c})\sqrt{f'_c}b_o d \leq 4\sqrt{f'_c}b_o d$ <p>psi</p>   |
| Segmental Construction  | AASHTO Guide Specs have been incorporated (5.14.2)   | Not included (see '99 AASHTO Guide Specs)   |
| STEEL   |  |   |
| Curved girders  | Addressed  | Not addressed   |
| Connections and splices   | 100% of factored axial, flexural, shear resistance of members (6.13.1, CA amendment to match BDS)  | 10.18, 10.19  |
| <p>Fatigue resistance (steel)</p> <ul style="list-style-type: none"> <li>weld detail categories</li> <li>stress range</li> </ul>  | <ul style="list-style-type: none"> <li>similar to AISC tables</li> <li><math>(\Delta F)_n = (\frac{A}{N})^{\frac{1}{3}} \geq \frac{1}{2}(\Delta F)_{TH};</math><br/>where <math>A</math> is a constant, <math>N = (365\text{days})(75\text{yr})(\text{ADTT})</math>, <math>\Delta F_{TH}</math> is specified in Table 6.6.1.2.5-3 for categories A through F</li> </ul>  | <ul style="list-style-type: none"> <li>similar to AISC tables</li> <li>specified in Table 10.3.1 for categories A through F</li> </ul>  |
| FOUNDATIONS   | DOWNLOAD '06 INTERIMS!!!   |   |
| <p>Spread Footings</p> <ul style="list-style-type: none"> <li>General</li> <li>Settlements</li> <li>Bearing pressure</li> <li>Factors of Safety</li> <li>Total scour</li> </ul> | <ul style="list-style-type: none"> <li>Very similar to Std. Spec 16<sup>th</sup> Ed. (BDS '00)</li> <li>Use service limit state</li> <li>Strength limit state; Terzaghi and Meyerhof's Eqn; inclined loading considered</li> <li>Strength F.S. = <math>\Sigma \gamma Q / \Sigma \phi R</math> where <math>\gamma</math> is between 1.25 and 1.75, <math>\phi</math> is between 0.45 and 0.90 (Table 10.5.5.2.1-1)</li> <li>Unfactored LL's; <math>\phi</math>'s = 1.0</li> </ul> | <ul style="list-style-type: none"> <li>OGS internal procedure used in lieu of BDS '00?</li> <li>Working stress used</li> <li>Working stress used; Terzaghi and Meyerhof's Eqn; inclined loading not considered</li> <li>F.S.=1.5 for sliding; 3.0 for bearing</li> <li>Not addressed</li> </ul> |



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| <p>Deep Foundations</p> <ul style="list-style-type: none"> <li>• Skin friction; uplift resistance</li> <li>• Punching thru strong soil into weaker soil</li> <li>• Depth of fixity</li> <li>• Factors of safety—strength</li> <li>• Total scour</li> </ul> | <ul style="list-style-type: none"> <li>• Provided; strength limit state</li> <li>• Suggested</li> <li>• Provided</li> <li>• F.S. = <math>\Sigma\gamma Q/\Sigma\phi R</math>, where <math>\phi</math>'s<br/>Piles—Table 10.5.5.2.2-1;<br/>Shafts—Table 10.5.5.2.3-1</li> <li>• Uplift resistance, <math>\phi = 0.8</math></li> </ul>  | <ul style="list-style-type: none"> <li>• OGS internal procedure</li> <li>• OGS internal procedure</li> <li>• Not published by OGS</li> <li>• F.S. = 2.0; Groups I-VI, <math>\phi = 0.75</math></li> <li>• Group VII, <math>\phi = 1.00</math></li> </ul>  |
| WALLS, ABUTS   |  |   |
| <p>Design Methodology</p>  | <ul style="list-style-type: none"> <li>• Service limit state for excessive movement; overall stability</li> <li>• Strength limit state for bearing, sliding, base contact, pullout of anchors, structural failure.<br/>Resistance factors in Table 11.5.6-1 (except structural)</li> </ul>   | <ul style="list-style-type: none"> <li>• Service load method</li> </ul>   |
| <p>Rigid Gravity Walls, Abuts</p> <ul style="list-style-type: none"> <li>• F.S.--Sliding, bearing</li> <li>• Ret. Wall stability</li> <li>• Overturning; bearing resistance</li> </ul>   | <ul style="list-style-type: none"> <li>• <math>\Sigma\gamma Q/\Sigma\phi R</math> where <math>\gamma</math> is between 1.25 and 1.75, <math>\phi</math> same as for spread ftgs</li> <li>• Service (stability): <math>\phi = 0.65</math> or 0.75 (11.6.2.3)</li> <li>• (Strength) eccentricity <math>&lt; B/4</math> (soil) or <math>3B/8</math> (rock)</li> <li>• <math>k_o = 1 - \sin\phi'</math> (3.11.5.2); <math>k_o = 1 - \sin\phi'(\text{OCR})^{\sin\phi'}</math></li> <li>• <math>k_a</math> (based on Coulomb, 3.11.5.3)</li> </ul> | <ul style="list-style-type: none"> <li>• F.S. <math>\geq 1.5</math> (sliding); 3.0 (bearing)</li> <li>• Trial Wedge Method (Chp. 5, Aug. '03)</li> <li>• eccentricity <math>&lt; B/6</math> (soil) or <math>B/4</math> (rock)</li> <li>• <math>k_o = 1 - \sin\phi'(1 + \sin\beta)</math> where <math>\beta</math> is slope angle of backfill (5.5.5.2); <math>k_p</math> after Navy '71 (same as '82)</li> <li>• <math>k_a</math> (Coulomb--5.5.5.3)</li> </ul> |
| <p>Non-gravity Cantilevered Walls</p>  | <p>11.8 Spacing between discrete vertical wall elements (11.8.5.2) addressed</p>   |   |
| <p>Anchored Walls</p> <ul style="list-style-type: none"> <li>• stability</li> <li>• soil failure</li> </ul>  | <p>11.9</p> <ul style="list-style-type: none"> <li>• same as ret. walls, above</li> <li>• <math>\Sigma\gamma Q/\Sigma\phi R</math> where <math>\gamma</math> is between 1.35 and 1.50, <math>\phi</math> is 0.90 for anchor tension, between 0.50 and 0.70 for rock/soil failure (<math>\phi=1.0</math> if</li> </ul>  | <p>F.S.=2.0 for structural anchor capacity (1.5 for safety against rotation)<br/>F.S.=1.5 for proof-tested ground anchor, 2.0 to 2.5 soil bond, 2.5 to 3.0 rock bond</p>  |

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|   | proof test is done)  |  |
| MSE Walls   | 11.10<br>FS varies for sliding, bearing, over-turning similar to spread footings: $\Sigma \gamma Q / \Sigma \phi R$<br>Coulomb Theory encouraged (simplifies to Rankine)   | F.S. $\geq 1.5$ for sliding<br>F.S. $\geq 2.0$ for overturning, and eccentricity $< B/6$<br>F.S. $\geq 2.0$ for bearing<br>Rankine Theory encouraged   |
| Prefab Modular Walls  | 11.11 <ul style="list-style-type: none"> <li>sliding--<math>\Sigma \gamma Q / \Sigma \phi R</math> where <math>\gamma</math> is between 1.25 and 1.75, <math>\phi</math> is same as spread footings</li> <li>bearing—<math>\Sigma \gamma Q / \Sigma \phi R</math> where <math>\gamma</math> is between 1.25 and 1.75, <math>\phi</math> is same as spread ftgs</li> <li>overturning—max 80% of soil-fill is effective resisting</li> </ul> | F.S. $\geq 1.5$ for sliding<br><br>F.S. $\geq 3.0$ for bearing<br><br>F.S. $\geq 2.0$ for overturning, and eccentricity $< B/6$  |
|   |  |  |
| CULVERTS<br>Load distribution   | Load—32 <sup>k</sup> axle (3.6.1.3.3): <ul style="list-style-type: none"> <li><math>&lt; 2</math> ft fill, traffic    to span—strip widths in 4.6.2.10.2; traffic 90° to span—treat as deck; <math>\geq 2</math> ft fill, spread from tire contact area to 1:1.15 times depth (3.6.1.2.6)</li> </ul>   | Load—HS-20 (6.3) <ul style="list-style-type: none"> <li>RC boxes: <math>&lt; 2</math> ft fill, treat as slab bridge; <math>\geq 2</math> ft fill, point load spread to 1:1.75 (6.5.2)</li> </ul> |
|   |  |  |
| RAILINGS <ul style="list-style-type: none"> <li>Design methodology</li> <li>Overhang design for collision load</li> </ul> | <ul style="list-style-type: none"> <li>Performance-based (Section 13; forces for design of specimen in A13)</li> <li>Load combo's and load distribution for parapets, post-and-beam, in A13.4</li> </ul>   | <ul style="list-style-type: none"> <li>Not addressed in Specs</li> <li>Not addressed in Specs</li> </ul>   |
|   |  |  |
| BRGS; JOINTS  |  |  |
| Steel elastomeric bearings  | <ul style="list-style-type: none"> <li>(14.7.5) Method B</li> <li>(14.7.6) Method A—requires more testing, QC</li> </ul>   | <ul style="list-style-type: none"> <li>(14.6.5)</li> <li>(14.6.6)</li> </ul>   |
| Modular joints  | Addressed (14.5.6.9)   | Not addressed  |